Ecosystems Unit Front Matter

Unit Home

Download PDF of Unit Front Matter

Ecosystems is one of the six *Carbon TIME* units. If you are new to teaching *Carbon TIME*, read the *Carbon TIME* FAQ: Which Units Should I Teach.

The *Ecosystems Unit* supports students in using core disciplinary ideas, science practices, and crosscutting concepts to develop scientific explanations of how different ecosystems *transform matter and energy* as the organisms in them live, grow, and die.

Follow these steps to get ready to teach the *Ecosystems Unit*

Step 1	Step 2	Step 3	Step 4	Step 5
Read The Unit Overview	Choose Your Unit Sequence	Learn About The Instructional Model & Storyline	Prepare Unit Materials	Dig Into The Lessons

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This unit is also available online at http://carbontime.bscs.org/. Contact the MSU Environmental Literacy Program for more information: EnvLit@msu.edu.

Overview

The goal of the *Ecosystems* unit is to introduce students to carbon cycling and energy flow in different terrestrial ecosystems, including natural ecosystems such a meadows and forests and ecosystems managed by humans such as farms. Students use pool-and-flux models to explain:

- how carbon cycles and energy flows in ecosystems,
- how humans alter carbon cycles to produce goods and services that we need, and
- how seasons and disturbances such as fires and floods alter the structure and function of ecosystems.

The Driving Question and Research Base

Download PDF of Unit Overview

The *Ecosystems* Unit starts by asking students to express their ideas about the driving question about an anchoring phenomenon, "How many foxes can live in a meadow?"

Carbon is the key! In the unit, students learn to tell the story of how matter and energy are transformed as they move through ecosystems. A particularly powerful strategy for explaining how ecosystems transform matter and energy involves *tracing carbon atoms*. For more information about the *Next Generation Science Standards* **disciplinary core ideas** included in this unit see the sections on the Large Scale Four Questions below and the Unit Goals.

Research base. This unit is based on learning progression research that describes the resources that students bring to learning about ecosystems and the barriers to understanding that they must overcome. It is organized around an Instructional Model that engages students in three-dimensional practices.

Students' Roles and Science Practices

As students learn to answer the driving question by explaining how ecosystems transform matter and energy, they play three different roles that encompass all of the *Next Generation Science Standards* **science and engineering practices**. (For more details on science and engineering practices, see the Unit Goals.)

- Questioners: Students explore the driving question, clarify, and generate more detailed questions
- Investigators: Students conduct investigations using a simulation of a meadow ecosystem and develop evidence-based arguments about key observations and patterns

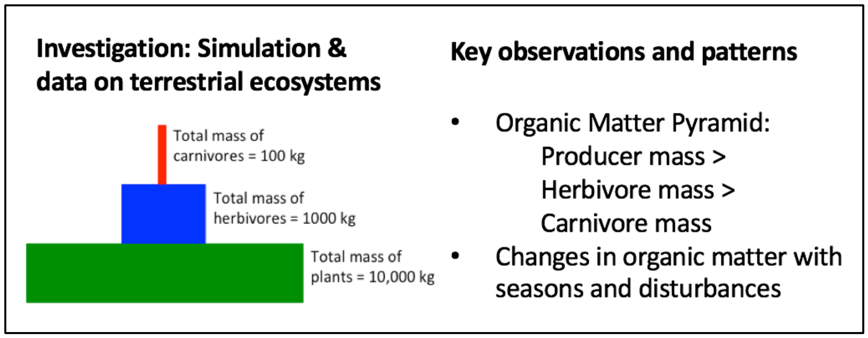

Figure 1: Results of investigation of a meadow simulation

- Explainers: Students construct model-based explanations of how carbon cycles and energy flows in different types of terrestrial ecosystems.

The roles that students play are embedded in the *Carbon TIME* Instructional Model and Discourse Routine. The Discourse Routine guides how classroom discourse aimed first at divergent thinking and then at convergent thinking should be sequenced through the unit.

Good Explanations Answer the Large-scale Four Questions

Students figure out how to answer the driving question by tracing carbon-containing molecules through a series of movements and chemical changes as they travel through different matter pools in ecosystems. At each stage in these processes they answer Four Questions about what is happening: The *Carbon Pools Question,* the *Carbon Cycling Question,* the *Energy Flow Question,* and the *Stability and Change Question.*

Note that, in *Carbon TIME*, *NGSS* **crosscutting concepts** serve as the “rules of grammar” for producing a scientific performance. With respect to ecosystems, high quality explanations should attend to the following rules that are implied by crosscutting concepts. Explanations should attend to:

- *Scale* by explaining events and phenomena at the appropriate scale (see more in the structure and function bullets below).
- *Systems and system models and energy and matter* by following rules for tracing matter and energy through systems and system models. For example, neither energy nor matter should be created or destroyed as it moves into, through, or out of a system.
- *Structure and function* by linking structures and functions in explanations at each scale.
    - Ecosystem scale (tracing fluxes of carbon and energy through different matter pools in ecosystems)
    - Macroscopic scale (tracing matter and energy through processes occurring inside plants, animals, and decomposers)
    - Atomic-molecular scale (tracing matter and energy through chemical processes—photosynthesis, digestion, cellular respiration, and biosynthesis—involving molecules with different structures and properties)

The Carbon Pools Question: Where are the carbon pools in our environment?

Students learn to answer the Large-scale Four Questions for different ecosystems, beginning with the anchoring phenomenon of a meadow ecosystem as an example. They identify five carbon pools in each ecosystem.

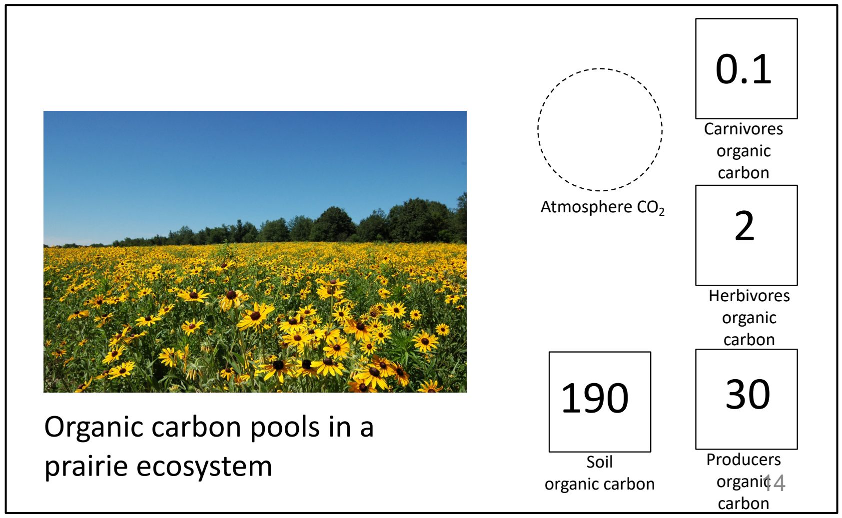

Figure 2: Carbon pools in all ecosystems

- Atmospheric carbon dioxide: the only inorganic carbon pool.
- Producers: the organic carbon in plants and other photosynthetic organisms
- Herbivores: animals that eat plants
- Carnivores: animals that eat animals
- Soil organic carbon: detritus such a fallen leaves, dead plants and animals, and decomposers that use organic materials in the soil as a food source

The Carbon Cycling and Energy Flow Questions: Explaining How Matter and Energy Move and Change in Ecosystems

Students begin the unit by investigating relationships among the sizes of carbon pools and find the pattern of relationships shown in Figures 1 and 2 above: The producer organic matter pool is much bigger than the herbivore pool, and the herbivore pool is much bigger than the carnivore pool.

Students learn to explain these patterns using *carbon fluxes* that move materials from one carbon pool to another. Carbon fluxes depend on processes, such as photosynthesis and cellular respiration, that take place inside individual organisms. They involve physical movement and chemical changes in matter, driven by changes in energy. Students study the carbon pools and fluxes shown in Figure 3 below.

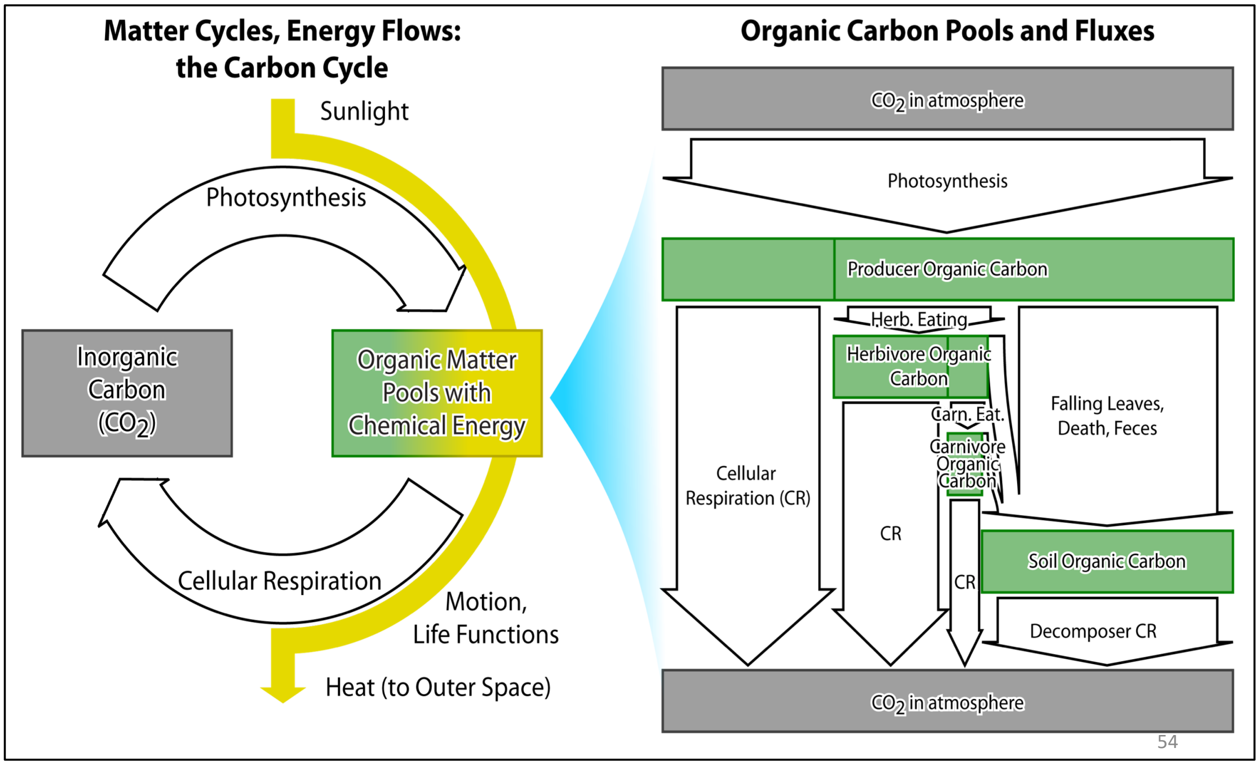

Figure 3: Carbon cycling and energy flow in terrestrial ecosystems

The big picture: The left side of Figure 3 shows the general pattern of carbon cycling and energy flow in all ecosystems:

- There are two big carbon pools: Carbon dioxide in the air and organic matter in living and dead organisms.
- There are two big carbon fluxes: Photosynthesis changes carbon dioxide and water into organic carbon and oxygen; cellular respiration completes the cycle, turning organic carbon and oxygen back into carbon dioxide and water.
- Energy flows through the ecosystem: Sunlight is converted into chemical energy in organic matter, which is released through cellular respiration, ultimately becoming heat that the Earth radiates into outer space.

Details of organic matter pools and fluxes: The right side of Figure 3 shows details of pools and fluxes inside the large organic matter pool. Food chains and food webs are a part of this story, but not the whole story. Plants use the organic materials that they create with photosynthesis for growth and energy (cellular respiration). The materials in plant bodies move to other pools when the plants are eaten or when dead plant materials become detritus in the soil. Ultimately organic materials are oxidized to carbon dioxide and water through cellular respiration in plants, animals, and decomposers.[1]

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[1] Some soil carbon can remain in the soil for a very long time, ultimately becoming fossil fuels. These processes are discussed in the *Human Energy Systems* Unit.

The Stability and Change Question: How do carbon fluxes change the size of carbon pools?

(Note: The Stability and Change Question is addressed mostly in Lesson 4, which is optional for middle school students since modeling of processes that change ecosystems is addressed primarily in *NGSS* High School Performance Expectations—see the Unit Goals tab.)

Ecosystems are constantly changing. Students learn to analyze how changes in ecosystems affect carbon pools and fluxes using quantitative online models (illustrated in Figure 4 below) and by studying cases of different ecosystems.

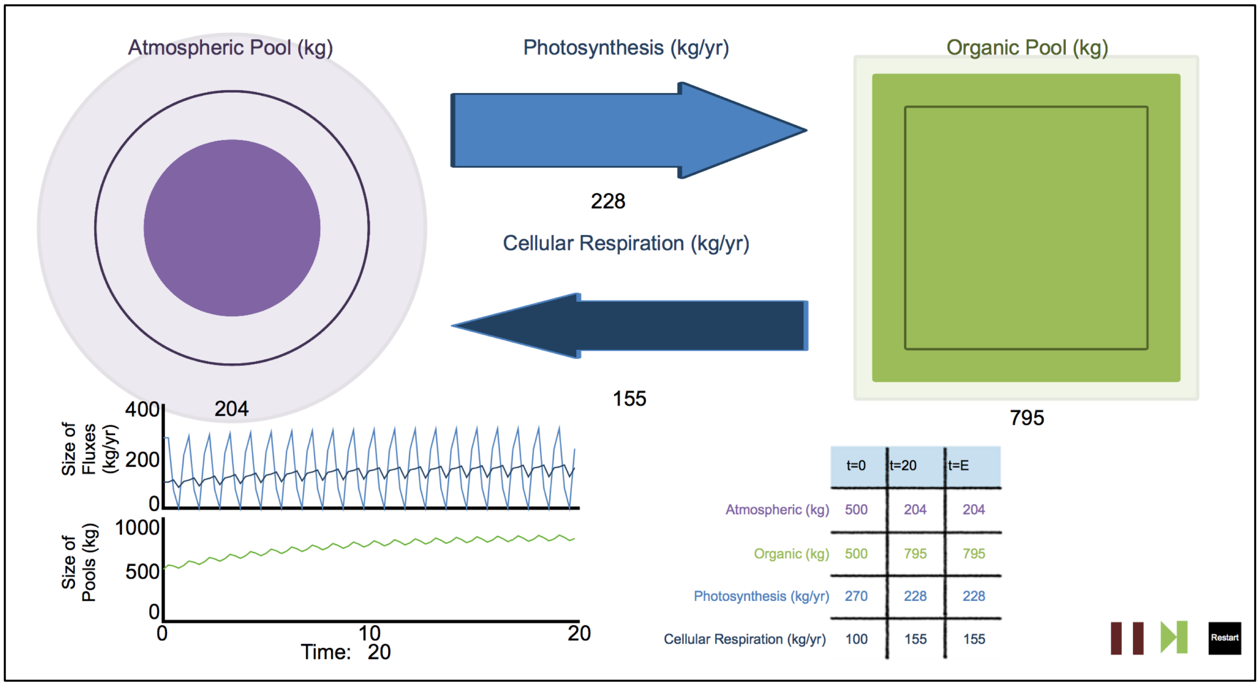


Figure 4: Computer simulation of pools and fluxes in an ecosystem with changing seasons

Students analyze how carbon cycling and energy flow are affected by three kinds of changes in ecosystems:

- *Seasonal changes* affect the photosynthesis flux in particular, changing the balance of fluxes and the sizes of the organic matter and CO_2 pools.
- *Human management* in ecosystems such as farms and ranches: Humans alter the environment so that ecosystems produce goods and services that we need.
- *Disturbances* such as fires and droughts change carbon fluxes and carbon pools.

How Much Detail?

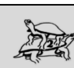
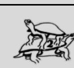
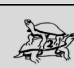
There are more complicated and more scientifically accurate ways of talking about chemical bonds and about changes in energy; we discuss some of those in detail in our educator resource: *Carbon TIME* Content Simplifications. But our learning progression research has shown that there is an important tradeoff here—many students get lost in the details and never learn a basic coherent story that answers the driving question. The *Next Generation Science Standards* take a clear position on this tradeoff; a coherent story based on principles such as matter and energy conservation is more important than the details. Consult the Unit Sequence tab and the sections on Extending the Learning at the end of each Activity page to decide how much detail is appropriate for your students.

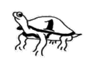
Unit Sequence

Before beginning the *Ecosystems Unit*, you need to decide what to teach and importantly, what not to teach! Use this page to choose the unit sequence that's most appropriate for your students.

Some activities are TWO-TURTLE ACTIVITIES (), which place a higher demand on students. Decide whether the higher demand required by these activities will be useful or distracting for y*our students*. The *Carbon TIME* Turtle Trails document provides further info about choices for making units more or less demanding, depending on your students' needs.

Unless otherwise noted in the table below, all activities in the unit should be taught.

Lesson	Activity Sequence	Feature	Make a Decision
1 (1 hr 30 min)	1.1 Ecosystems Unit Pretest (20 min)		
	1.2 Expressing Ideas and Questions for Patterns in Ecosystems (40 min)		
	1.3 Carbon Pools (30 min)		
2 (2 hr 20 min)	2.1 Predictions and Planning for Meadow Simulation (30 min)		
	2.2 The Meadow Simulation (50 min)		
	2.3 Evidence-Based Arguments for Meadow Simulation (40 min)		
	2.4 Organic Carbon Pools in Other Ecosystems (20 min)		
3 (2 hr 50 min)	3.1 Large-Scale Four Questions (20 min)		
	3.2 Carbon Dice Game (30 min)		
	3.3 Tracing Carbon Through an Ecosystem (30 min)		
	(Optional) 3.4 What Happens to Soil Carbon? (30 min)		Activity 3.4 provides students with additional information on soil carbon. Consider your students and learning goals when deciding whether to use this activity.
	3.5 Tracing Energy Through an Ecosystem (30 min)		
	3.6 Explaining Patterns in Ecosystems (30 min)		
4 (2 hr 20 min)	4.1: Tiny Pool and Flux Game (30 min)		Activities 4.1, 4.2, 4.3, and 4.4 are 2-turtle activities, which introduces a quantitative model of carbon pools and fluxes, then uses that model to explain how ecosystems change over time. This is challenging content that addresses NGSS High School Performance
	4.2: Carbon Pools and Constant Flux Simulation (30 min)		
	4.3: How Fluxes Change and Photosynthesis Limits (40 min)		

	4.4: Seasonal Changes and Ecosystem Disturbances (40 min)		Expectations. You may want to skip it with middle school classes.
5 (2 hr 30 min)	5.1: Introduction to Ecosystem Products and Services (40 min)		
	5.2: Ecosystem Products and Services Jigsaw (50 min)		Activity 5.2 engages students in reading about three different managed ecosystems. You probably don't want every student to do a worksheet on all three ecosystems, so there are several ways that students could become "experts" on one ecosystem, then compare what they have learned with other students (e.g., a jigsaw activity, working in groups to make posters).
	5.3a: Ecosystem Posters (40 min) **OR**		Activity 5.3 has a 1-turtle version (5.3a) appropriate for middle school students and a 2-turle version (5.3b) appropriate for high school students that completed Lesson 4 as it includes ecosystem disturbances and their effects. Consider the level of your students when choosing which version of this activity to teach.
	5.3b: Ecosystem Posters (40 min)		
	5.4: Ecosystems Unit Posttest (20 min)		

IM & Storyline

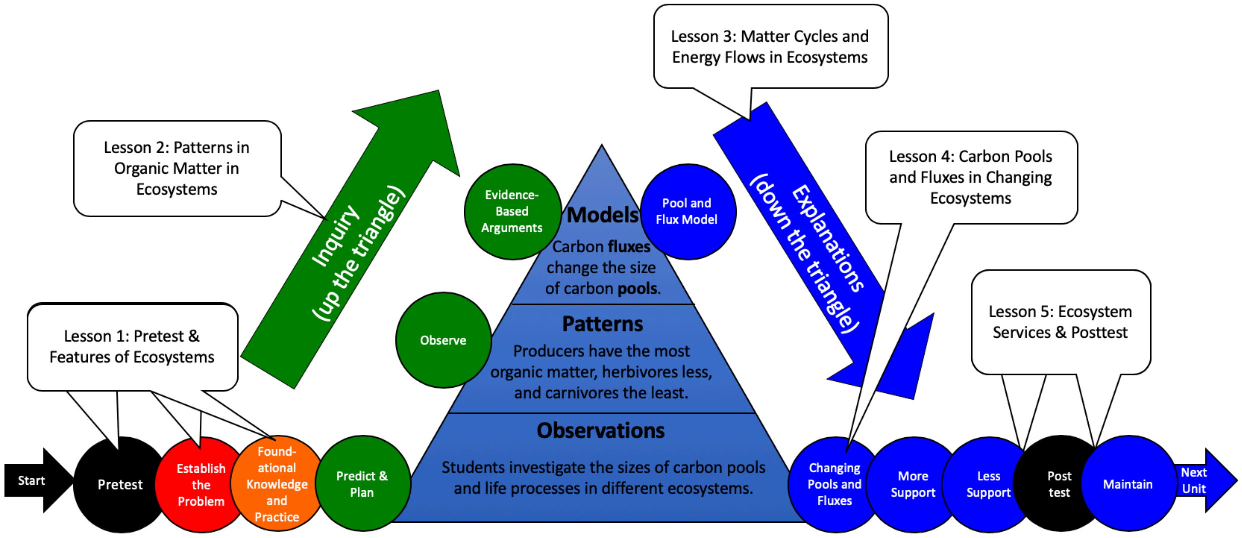
Here, we present two ways to think about how lessons are sequenced in the *Ecosystems* Unit. The Instructional Model, immediately below, emphasizes how students take on roles of questioner, investigator, and explainer to learn and apply scientific models they can use to answer the driving question. Further below, the Unit Storyline Chart highlights the central question, activity, and answer that students engage with in each lesson of the *Ecosystems* Unit.

Instructional Model

Like all *Carbon TIME* units, this unit follows an Instructional Model (IM) designed to support teaching that helps students achieve mastery at answering the driving question through use of disciplinary content, science practices, and crosscutting concepts. To learn more about this design, see the *Carbon TIME* Instructional Model.

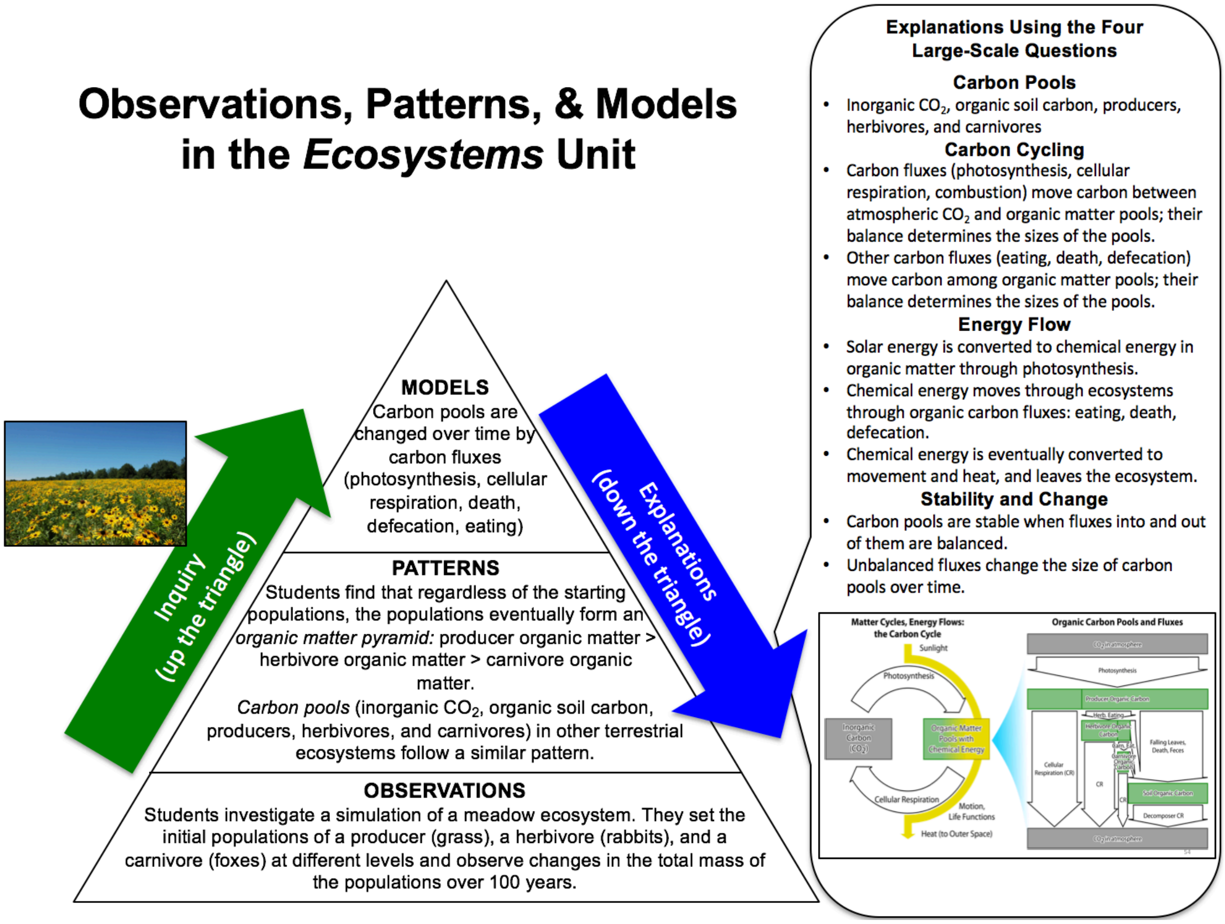
During the inquiry portion of the unit (Lesson 2), the students move from making observations of a simulated meadow ecosystem to identifying patterns, eventually using these patterns to make evidence-based arguments. During the explanation portion of the unit (Lessons 3, 4, and 5), students makes connections across scales (from atomic-molecular scale to ecosystem scale) to explain patterns and changes in ecosystems. Across the unit, classroom discourse is a necessary part of three-dimensional *Carbon TIME* learning. The *Carbon TIME* Discourse Routine document provides guidance for scaffolding this discourse in lessons.

The *Ecosystems* Unit



The core of the *Carbon TIME* IM is the Observation, Patterns, Models (OPM) triangle, which summarizes key aspects to be attended to as the class engages in unit inquiry and explanation. The OPM triangle for the *Ecosystems* Unit, shown below, articulates the key observations students make during the unit investigation, the key patterns they identify through analyzing their investigation data, and the central scientific model that can be used to answer the unit's driving question.

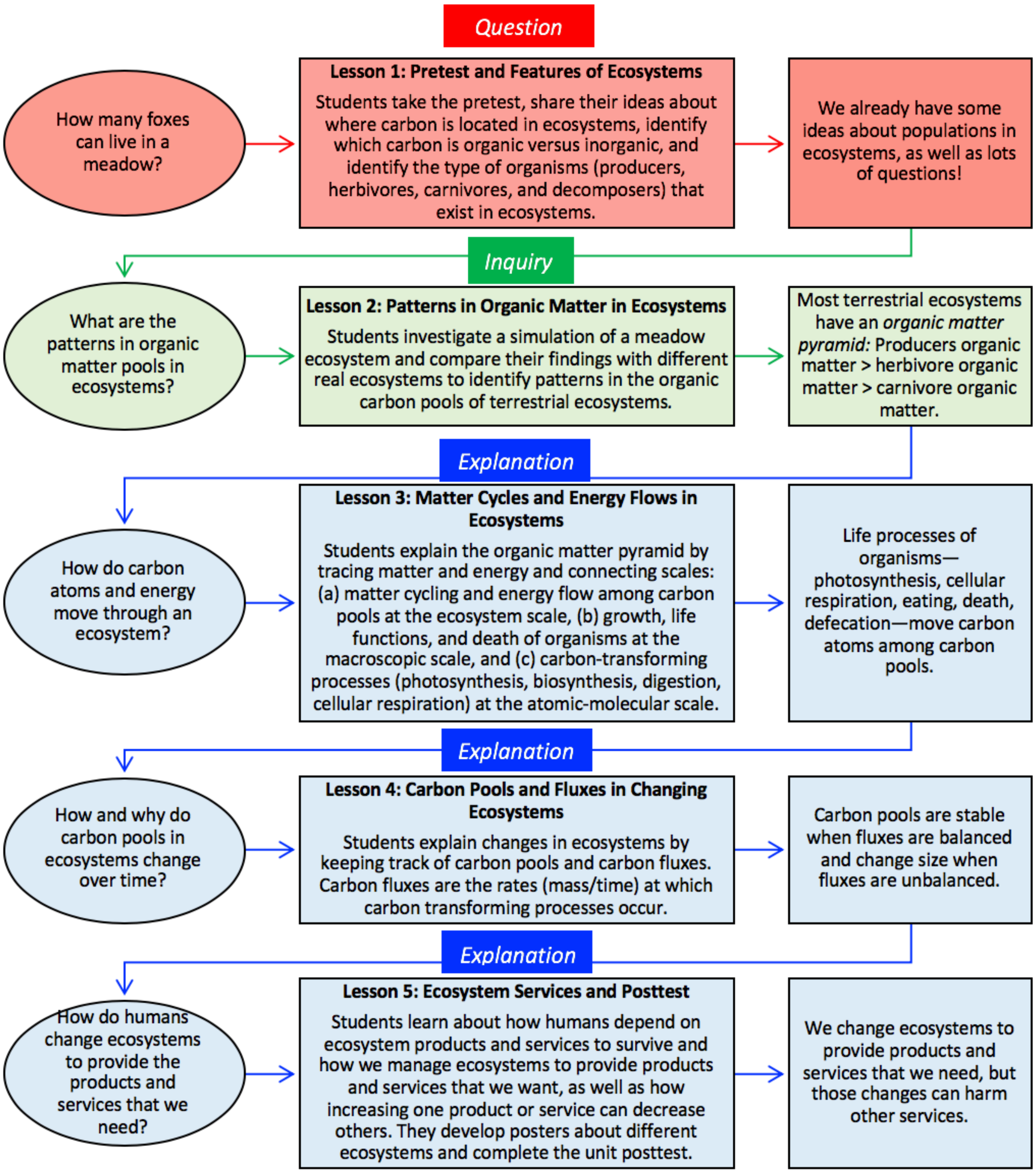
Observations, Patterns, Models, and Explanations in the Ecosystems Unit



Unit Storyline Chart

Download PDF of Unit IM and Storyline Chart

Another way to familiarize yourself with the sequence of lessons in the *Ecosystems* Unit is with the Unit Storyline Chart depicted below. The Unit Storyline Chart summarizes a unit phenomenon-based driving question associated with each lesson, what classes will do in each lesson to address the question, what conclusions they will come to, and how they will transition to a subsequent lesson.



Unit Goals

The tables below show goals for this unit in two forms. A table showing specific target performances for each activity is followed by a list of the *Next Generation Science Standards (NGSS)* addressed by this unit.

Target Performances for Each Activity

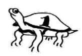
Download PDF of Unit Target Performances

All *Carbon TIME* units are organized around a common purpose: *assessing and scaffolding students' three-dimensional engagement with phenomena.* Every *Carbon TIME* activity has its specific expectation for students' three-dimensional engagement with phenomena, what we call its **target performance**. Each activity also includes tools and strategies that teachers can use to asses and scaffold the target performance in rigorous and responsive ways.

The target performances for each activity in the *Ecosystems* unit are listed in the table below.

Activity	***Target Performance***
Lesson 1 – Pretest and Features of Ecosystems (students as questioners)	
Activity 1.1: Ecosystems Unit Pretest	Students show their initial proficiencies for the overall unit goal: Questioning, investigating, and explaining how carbon cycles and energy flows in ecosystems.
Activity 1.2: Expressing Ideas and Questions for Patterns in Ecosystems	Students ask and record specific questions about changes in matter and energy in response to the unit driving question: How many foxes can live in a meadow?
Activity 1.3: Carbon Pools	Students identify where carbon atoms are located in ecosystems and groups of organisms that have similar functions (carbon pools).
Lesson 2 – Patterns in Organic Matter in Ecosystems (students as investigators)	
Activity 2.1: Predictions and Planning for the Meadow Simulation	Students make predictions about changes in the mass of different populations in a meadow ecosystem and plans to maximize the fox population.
Activity 2.2: The Meadow Simulation	Students identify patterns in relationships among organic mass of populations at different trophic levels in a simulated meadow ecosystem (the organic matter pyramid).
Activity 2.3: Evidence-Based Arguments for Meadow Simulation	Students develop arguments from evidence about possible patterns in relationships among mass of populations at different trophic levels in a simulated meadow ecosystem (the organic matter pyramid).
Activity 2.4: Organic Carbon Pools in Other Ecosystems	Students describe patterns in relationships among mass of populations at different trophic levels in a other ecosystems (the organic matter pyramid).

Activity	**_Target Performance_**
Lesson 3 – Matter Cycles and Energy Flows in Ecosystems (students as explainers)	
Activity 3.1: Large-Scale Four Questions	Students identify carbon pools in ecosystems and processes that move carbon atoms from one pool to another.
Activity 3.2: Carbon Dice Game	Students record and share data about their movement to different carbon pools when they play the role of carbon atoms in an ecosystem (the Carbon Dice Game).
Activity 3.3: Tracing Carbon Through an Ecosystem	Students name carbon pools and the processes that move carbon atoms among pools in terrestrial ecosystems.
(Optional) Activity 3.4: What Happens to Soil Carbon?	Students explain the role of detritus and detritus-based food chains in ecosystems.
Activity 3.5: Tracing Energy Through an Ecosystem	Students trace changes in energy and energy flow through carbon pools in ecosystems.
Activity 3.6: Explaining Patterns in Ecosystems	Students explain matter cycling and energy flow in ecosystems, answering the Carbon Pools Question, the Carbon Cycling Question, and the Energy Flow Question.
Lesson 4 – Carbon Pools and Fluxes in Changing Ecosystems (students as explainers)	
Activity 4.1: Tiny Pool and Flux Game	Students describe the relationship between pools and fluxes in a physical model: changes in pool sizes depend on balance among fluxes.
Activity 4.2: Carbon Pools and Constant Flux Simulation	Students describe the relationship between pools and fluxes in an online computer model: changes in pool sizes depend on balance among fluxes.
Activity 4.3: How Fluxes Change and Photosynthesis Limits	Students use an online computer model to describe how changes in carbon pools over time depend on the maximum possible rate of photosynthesis in an ecosystem.
Activity 4.4: Seasonal Changes and Ecosystem Disturbances	Students use an online computer model to describe how seasons and disturbances affect an ecosystem.
Lesson 5 – Ecosystem Services and Posttest (students as explainers)	
Activity 5.1: Introduction to Ecosystem Products and Services	Students explain how humans change matter cycling and energy flow in ecosystems to produce products and services.

Activity	*Target Performance*
Activity 5.2: Ecosystem Products and Services Jigsaw	Students explain how humans manage matter cycling and energy flow in specific ecosystems to produce products that they need (beef, corn, forest).
 Activity 5.3a: Ecosystem Posters **OR**	Students use posters to explain matter cycling, energy flow, and ecosystem services in a different ecosystem.
 Activity 5.3b: Ecosystem Posters	Students use posters to explain matter cycling, energy flow, ecosystem services, and effects of disturbances in a different ecosystem.
Activity 5.4: Ecosystems Unit Posttest	Students show their end-of unit proficiencies for the overall unit goal: Questioning, investigating, and explaining how carbon cycles and energy flows in ecosystems.

Next Generation Science Standards

The *Next Generation Science Standards* (*NGSS*) Performance Expectations that middle and high school students can achieve through completing the *Ecosystems* Unit are listed below. To read a discussion of how the *Carbon TIME* project is designed to help students achieve the performances represented in the *NGSS*, please see Three-dimensional Learning in *Carbon TIME*.

High School

- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-1. Use mathematical and or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales. https://www.nextgenscience.org/pe/hs-ls2-1-ecosystems-interactions-energy-and-dynamics
- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems at different scales. https://www.nextgenscience.org/pe/hs-ls2-2-ecosystems-interactions-energy-and-dynamics
- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-3. Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions. https://www.nextgenscience.org/pe/hs-ls2-3-ecosystems-interactions-energy-and-dynamics
- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-4. Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem. https://www.nextgenscience.org/pe/hs-ls2-4-ecosystems-interactions-energy-and-dynamics
- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-5: Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. https://www.nextgenscience.org/pe/hs-ls2-5-ecosystems-interactions-energy-and-dynamics

- Ecosystems: Interactions, Energy, and Dynamics. HS-LS2-6: Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem. https://www.nextgenscience.org/pe/hs-ls2-6-ecosystems-interactions-energy-and-dynamics
- Earth's Systems. HS-ESS2-6. Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere. http://www.nextgenscience.org/hsess-es-earth-systems

Middle School

- Matter and Energy in Organisms and Ecosystems. MS-LS1-6. Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy in and out of organisms. http://www.nextgenscience.org/msls1-molecules-organisms-structures-processes
- Matter and Energy in Organisms and Ecosystems. MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. http://www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics
- Interdependent Relationships in Ecosystems. MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems. http://www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics
- Matter and Energy in Organisms and Ecosystems. MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem. http://www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics
- Matter and Energy in Organisms and Ecosystems. MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. http://www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics
- Earth's Systems. MS-ESS2-1. Develop a model to describe the cycling of earth's materials and the flow of energy that drives this process. http://www.nextgenscience.org/msess-es-earth-systems
- Human Impacts. MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. http://www.nextgenscience.org/msess-hi-human-impacts

Materials

Recurring Resources

- (Optional) Big Idea Probe: Wolves and Deer (1 per student)
- (Optional) Assessing the Big Idea Probe: Wolves and Deer
- Learning Tracking Tool for Ecosystems (1 per student)
- Assessing the Learning Tracking Tool for Ecosystems
- Large Scale Four Questions Handout with Checklist (1 per student)
- Large Scale Four Questions Poster

- Using Big Idea Probes
- Questions, Connections, Questions Reading Strategy Educator Resource
- Questions, Connections, Questions Student Reading Strategy

Resources You Provide

Activity 1.1: Ecosystems Unit Pretest (20 min)

- Pencils (1 per student)

Activity 1.2: Expressing Ideas and Questions for Patterns in Ecosystems (15 min)

- Sticky notes (1 for each student)

Activity 2.2: The Meadow Simulation (50 min)

- Computers with internet access (1 per pair of students)

Activity 2.3: Evidence-Based Arguments for the Meadow Simulation (40 min)

- (From previous activity) 2.2 Meadow Simulation Worksheet

Activity 3.2: Carbon Dice Game (30 min)

- Containers to put twist ties in (one for each pool)
- Die (1 for each student)
- Yellow twist ties (at least 300)

Activity 3.3: Tracing Carbon Through Ecosystems (30 min)

- (From previous activity) 3.2 Carbon Dice Game Tracking Sheet

Activity 4.1: Tiny Pool and Flux Game (30 min)

- Markers such as M&Ms or bingo chips (10 per student or pair of students)

Activity 4.2: Carbon Pool and Constant Flux Simulation (30 min)

- Computers with internet access (1 per student or pair of students)

Activity 4.3: How Fluxes Change and Photosynthesis Limits (40 min)

- Computers with internet access (1 per student or pair of students)

Activity 4.4: Seasonal Changes and Ecosystem Disturbances (40 min)

- Computers with internet access (1 per student or pair of students)

Activity 5.3a: Ecosystem Posters (40 min)

- Poster paper or boards (1 per group)

Activity 5.3b: Ecosystem Posters (40 min)

- Poster paper or boards (1 per group)

Activity 5.4: Ecosystems Unit Posttest (20 min)

- Pencils (1 per student)

Resources Available on the Website

Activity 1.1: Ecosystems Unit Pretest (20 min)

- 1.1 Ecosystems Unit Pretest (1 per student)

- 1.1 Assessing Ecosystems Unit Pretest

Activity 1.2: Expressing Ideas and Questions for Patterns in Ecosystems (40 min)

- 1.2 Expressing Ideas and Questions for Patterns in Ecosystems PPT
- 1.2 Expressing Ideas and Questions Tool for Ecosystems (1 per student)
- 1.2 Assessing Expressing Ideas and Questions Tool for Ecosystems
- 1.2 Ecosystems Storyline Reading: Learning from the Work of Bonnie McGill (1 per student)

Activity 1.3: Carbon Pools (30 min)

- 1.3 Carbon Pools PPT
- 1.3 Carbon Pools Reading (1 per student)

Activity 2.1: Predictions and Planning for the Meadow Simulation (30 min)

- 2.1 Predictions and Planning for the Meadow Simulation PPT
- 2.1 Predictions and Planning Tool for the Meadow Simulation (1 per student)
- 2.1 Assessing Predictions and Planning Tool for the Meadow Simulation

Activity 2.2: The Meadow Simulation (50 min)

- The Meadow Simulation (https://carbontime.bscs.org/sites/default/files/simulations/eco-simulation/index.html)
- 2.2 Meadow Simulation PPT
- 2.2 Meadow Simulation Worksheet (1 per student)
- 2.2 Assessing Meadow Simulation Worksheet

Activity 2.3: Evidence-Based Arguments for the Meadow Simulation (40 min)

- 2.3 Evidence-Based Arguments for the Meadow Simulation PPT
- 2.3 Evidence-Based Arguments Tool for the Meadow Simulation (1 per student)
- 2.3 Assessing the Evidence-Based Arguments Tool for the Meadow Simulation

Activity 2.4: Organic Carbon Pools in Other Ecosystems (20 min)

- 2.4 Organic Carbon Pools in Other Ecosystems PPT

Activity 3.1: Large-Scale Four Questions (20 min)

- 3.1 Large-Scale Four Questions PPT

Activity 3.2: Carbon Dice Game (30 min)

- 3.2 The Carbon Dice Game PPT
- 3.2 Carbon Dice Game Tracking Sheet (1 per student)
- 3.2 Carbon Dice Game Posters (1 per class)
- 3.2 Carbon Dice Game Tally Cards (1 per class)
- 3.2 Carbon Dice Game Energy Labels (1 per class)
- 3.2 Carbon Dice Game Class Results Spreadsheet

Activity 3.3: Tracing Carbon Through an Ecosystem (30 min)

- 3.3 Tracing Carbon Through Ecosystems PPT
- 3.3 Tracing Carbon Through Ecosystems Graphic Organizer (1 per student)
- 3.3 Assessing Tracing Carbon Through Ecosystems Graphic Organizer
- (Optional) 3.3 Supplemental PPT

(Optional) Activity 3.4: What Happens to Soil Carbon? (30 min)

- 3.4 Food Webs Video Worksheet (1 per student)
- 3.4 Grading the Food Webs Video Worksheet

Activity 3.5: Tracing Energy Through an Ecosystem (30 min)

- 3.5 Tracing Energy PPT
- 3.5 Tracing Energy Worksheet (1 per student)
- 3.5 Grading the Tracing Energy Worksheet

Activity 3.6: Explaining Patterns in Ecosystems (30 min)

- 3.6 Explaining Patterns in Ecosystem PPT
- 3.6 Explanations Tool for Ecosystems (1 per student)
- 3.6 Grading the Explanations Tool for Ecosystems
- 3.6 Telling the Ecosystems Story Reading (1 per student)

Activity 4.1: Tiny Pool and Flux Game (30 min)

- 4.1 Tiny Pool and Flux Worksheet (1 per student)
- 4.1 Grading the Tiny Pool and Flux Worksheet
- 4.1 Tiny Pool and Flux Game Placemat (1 per student or pair of students)
- 4.1 Tiny Pool and Flux Game PPT

Activity 4.2: Carbon Pool and Constant Flux Simulation (30 min)

- 4.2 Carbon Pools and Constant Flux Simulation PPT
- Constant Flux Simulation (https://carbontime.bscs.org/sites/default/files/simulations/pool-flux-simulation-updated/index.html)
- 4.2 Computer Model for Constant Flux Worksheet (1 per student)
- 4.2 Grading the Computer Model for Constant Flux Worksheet

Activity 4.3: How Fluxes Change and Photosynthesis Limits (40 min)

- 4.3 How Fluxes Change and Photosynthesis Limits PPT
- Changing Flux Simulation (https://carbontime.bscs.org/sites/default/files/simulations/pool-flux-simulation-updated/index.html)
- 4.3 Computer Model for Changing Fluxes Handout (1 per student)
- 4.3 Computer Model for Changing Fluxes Worksheet (1 per student)
- 4.3 Grading the Computer Model for Changing Fluxes Worksheet

Activity 4.4: Seasonal Changes and Ecosystem Disturbances (40 min)

- 4.4 Seasonal Changes and Ecosystem Disturbances PPT
- Seasonal Changes and Disturbances Simulation (https://carbontime.bscs.org/sites/default/files/simulations/pool-flux-simulation-updated/index.html)
- 4.4 Computer Model for Seasons and Disturbances Handout (1 per student)
- 4.4 Computer Model for Seasons and Disturbances Worksheet (1 per student)
- 4.4 Grading the Computer Model for Seasons and Disturbances Worksheet
- (Optional) 4.4 Fire Reading (1 per student)

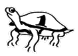
Activity 5.1: Introduction to Ecosystem Products and Services (40 min)

- 5.1 Introduction to Ecosystem Products and Services PPT
- 5.1 Ecosystem Images (1 set per class)
- 5.1 Ecosystem Products and Services Reading (1 per student)

- 5.1 Products and Services in Different Ecosystems Worksheet (1 per student)
- 5.1 Assessing Products and Services in Different Ecosystems Worksheet

Activity 5.2: Ecosystem Products and Services Jigsaw (50 min)

- 5.2 Ecosystem Products and Services Jigsaw PPT
- 5.2 Beef Ecosystem Products and Services Reading
- 5.2 Corn Ecosystem Products and Services Reading
- 5.2 Forest Ecosystem Products and Services Reading
- 5.2 Beef Ecosystem Products and Services Worksheet
- 5.2 Corn Ecosystem Products and Services Worksheet
- 5.2 Forest Ecosystem Products and Services Worksheet
- 5.2 Grading Beef Ecosystem Products and Services Worksheet
- 5.2 Grading Corn Ecosystem Products and Services Worksheet
- 5.2 Grading Forest Ecosystem Products and Services Worksheet


Activity 5.3a: Ecosystem Posters (40 min)

- 5.3a Ecosystem Review PPT
- 5.3a Ecosystem Posters Handout (1 per group)


Activity 5.3b: Ecosystem Posters (40 min)

- 5.3b Ecosystem Posters PPT
- 5.3b Ecosystem Posters Handout (1 per group)

Activity 5.4: Ecosystems Unit Posttest (20 min)

- 5.4 Ecosystems Unit Posttest (1 per student)
- 5.4 Grading the Ecosystems Unit Posttest